Appendix A: Review of Air Emissions Studies

This appendix presents ATSDR's review of measured air emission rates from the TSCA Incinerator. To date, emissions data have been generated during trial burns, performance tests, and continuous monitoring and continuous sampling evaluations. The following discussion defines these different types of tests and reviews the emissions data that each test measured. Overall, the emissions data provide an extensive account of the TSCA Incinerator's air releases for many pollutants. With three exceptions, the data reviewed in this appendix strongly suggest that the incinerator routinely destroys organic compounds at the required efficiencies while not exceeding maximum emission rates for selected contaminants.

The three exceptions are instances in which measured emission rates did not meet existing regulatory requirements or requirements that regulatory agencies would later implement. First, *before routine operations began*, a performance test in 1988 using surrogate non-waste materials found that beryllium and lead emissions were higher than those to be included in TDEC's air permits. The elevated emissions, however, probably resulted from miscalculations of waste feed rates. A follow-up test and all future performance tests have shown that the actual beryllium and lead emissions are considerably lower than the maximum levels allowed. Second, a recent trial burn performed to demonstrate compliance with RCRA emission limits found a particulate emission rate slightly higher than the maximum levels allowed in the state permit. This finding is likely not representative of actual emission rates for two reasons: trial burns challenge incinerator performance under very unfavorable operating conditions, and particulate emission rates measured during several performance tests (which better represent actual operating conditions) fell well within the air permit limit. ATSDR is further comforted by the fact that the extremely large volume of ambient air monitoring data for particulate matter, beryllium, and lead have shown that these contaminants do not reach harmful levels at off-site locations (see Appendix C). Third, continuous emissions sampling data collected in 2000 and 2001 suggest that the combined amounts of cadmium and lead in stack gases did not always meet levels that EPA has since established in its technology-based standards. This statement is not intended to imply that the TSCA Incinerator failed to comply with the MACT standards, because those standards were not enacted until 2 years after the sampling occurred. Fortunately, considerable ambient air monitoring data are available to evaluate these contaminants further.

In Section III.B of this PHA, ATSDR briefly summarizes the emissions data presented in this appendix. Section III.E places the emissions data in context with the two other critical elements of the air exposure pathway (i.e., fate and transport and ambient air monitoring).

A.1. Trial Burns

State and federal environmental agencies require incineration facilities to perform trial burns to demonstrate compliance with regulatory requirements and to establish limits on operating conditions for permitting purposes. At a minimum, trial burns must be performed *before* hazardous waste incinerators begin routine operations; multiple trial burns may be required at some facilities, depending on the regulatory requirements and significant changes in the waste feeds. Trial burns are very extensive and expensive tests that challenge incinerators to achieve required destruction efficiencies and compliance with emission limits, all while the facility operates under conditions unfavorable to complete combustion (e.g., high feed rates, low combustion temperatures, high stack flow rates).

Following is ATSDR's technical review of the trial burns that DOE has conducted at the TSCA Incinerator.6 Tables A-1 and A-2 summarize the main findings from the trial burns. Overall, the trial burns demonstrated that the TSCA Incinerator is capable of destroying organic material in waste streams, including PCBs, without creating hazardous residuals or unsafe air emissions.

May 1988 TSCA Trial Burn (Engineering-Science 1988a)

The first trial burn to evaluate the incinerator's efficiency at destroying PCBs was conducted in May 1988. The trial burn involved six individual tests, each of which lasted at least 6 hours. The tests evaluated two different types of feed:

The first type of waste was a mixture of liquid and solid wastes that included contaminated soil, capacitors, PCB oil, and aqueous waste. These wastes were fed to both the primary and secondary combustion chambers. During the three tests of this feed type, the primary combustion chamber's temperature was 1,800 degrees Fahrenheit, and the secondary combustion chamber's temperature was 2,200 degrees Fahrenheit.

The second type of waste was only solid material fed to the primary combustion chamber; these wastes included contaminated soil, shredded capacitors, and contaminated sludge. This waste was treated at lower temperatures: roughly 1,550 degrees Fahrenheit in the primary combustion chamber, and 1,850 degrees Fahrenheit in the secondary combustion chamber.

For both waste types, the average feed rate was 1,600 pounds per hour, which included approximately 250 pounds per hour of PCBs. Both state and federal officials observed the trial burn, which used well-established sampling and analytical methodologies for all measurements.

As Table A-1 shows, PCBs were measured in the stack gases to determine how efficiently the incinerator destroyed the waste material. In all six tests, PCBs were detected in the stack gases, but the detected amounts indicated that the incinerator's DRE was 99.99997% for both types of wastes. Thus, the trial burn demonstrated that the incinerator's DRE met the minimum requirement of TSCA regulations (99.9999%). Other key findings during the trial burn were that stack gas concentrations of particulate matter and hydrogen chloride removal efficiencies both fell well within limits later set in RCRA permits. Additionally, PCB concentrations in the process residuals met TSCA requirements: the ash generated during the tests contained less than 2 ppm PCBs, and the wastewater contained less than 3 ppb PCBs. After this trial burn EPA issued DOE a letter that approved use of the TSCA Incinerator to treat wastes containing PCBs (EPA 1989).

6 In addition to the "official" trial burns listed in this section, ATSDR also reviewed results of an initial performance test conducted in July 1987 (PEI/Metcalf and Eddy 1987). That performance test provided a preliminary evaluation of the TSCA Incinerator's ability to destroy organic compounds, including PCBs. The performance test included seven individual stack tests, all of which showed that the incinerator would likely meet the DRE requirements for both RCRA and TSCA without exceeding emissions limits for particulate matter or hydrogen chloride.

Table A-1. Summary of TSCA Trial Burn Data

Requirements	***Results from May 1988 TSCA Trial Burn***	***Results from May 2001 TSCA Trial Burn***
DRE for PCBs required to be at least 99.9999%	DRE = 99.99997%	DRE was >99.9999996%
PCB concentration in scrubber water blow-down must be less than 3 ppb	PCB concentration: <3 ppb	PCB concentration: <3 ppb (Highest level detected was 0.63 ppb)
PCB concentration in ash not to exceed 2 ppm	PCB concentration: < 2 ppm	PCB concentration: <2 ppm (Highest level detected was 0.017 ppm)
Other notable findings	The average particulate concentration in stack gases was 0.048 grains/dscf, which is lower than the RCRA permit requirement of 0.08 grains/dscf); the average emission rate of hydrogen chloride was 0.11 pounds/hour, which is lower than the RCRA permit requirement of 4.0 pounds/hour.	Dioxins and furans were not detected in the stack gases. Based on the detection limits used, the total stack gas concentration of dioxins and furans was <0.054 ng/dscm on a TEQ basis. This emission rate meets EPA's MACT emission rate limit of 0.2 ng/dscm on a TEQ basis.

Notes: Sources of data: Engineering-Science 1988a; TRC 2001.

The first three rows present the main TSCA requirements for the incinerator (i.e., the incinerator must be able to destroy PCBs, without generating hazardous residuals). The additional information provided summarizes additional observations reported in the trial burn reports that relate to regulatory requirements outside of TSCA.

Table A-2. Summary of RCRA Trial Burn Data

Parameter	*RCRA Requirement*	*Results from RCRA Trial Burns*		
		June 1988 Test	*June 1989 Test*	**May 2001 Test**
DRE for POHCs	>99.99%	POHC 1: 99.99976% POHC 2: 99.9997%	POHC 1: >99.9988% POHC 2: 99.998% POHC 3: >99.9974%	POHC 1: >99.999999% POHC 2: >99.999907%
Stack gas concentration of particulate matter	<0.08 grains/dscf	Average: 0.028 grains/dscf Maximum: 0.041 grains/dscf	Average: 0.0249 grains/dscf Maximum: 0.0327 grains/dscf	Average: 0.0455 grains/dscf Maximum: 0.064 grains/dscf
HCl emission rate	<4.0 lb/hour	Average: 0.13 lb/hour Maximum: 0.358 lb/hour	Average: 0.24 lb/hour Maximum: 0.32 lb/hour	Average: 0.07 lb/hour Maximum: 0.11 lb/hour
HCl removal efficiency	>99%	>99.9%	>99.912%	>99%

Notes: Sources of data: Engineering-Science 1988b; IT Corporation 1989; TRC 2001.
In the June 1988 test, the POHCs were (1) carbon tetrachloride and (2) trichlorofluoromethane. In the June 1989 test, the POHCs were (1) carbon tetrachloride, (2) trichlorofluoromethane, and (3) hexachloroethane. In the May 2001 test, the POHCs were (1) carbon tetrachloride and (2) 1,2,4-trichlorobenzene.
For HCl, RCRA regulations require operators of hazardous waste incinerators to demonstrate that either the HCl emission rate is less than 4 lb/hour or, in cases where emissions exceed this level, that HCl removal efficiencies are at least 99%.

June 1988 RCRA Trial Burn (Engineering-Science 1988b)

In June 1988, contractors to DOE conducted a trial burn to demonstrate that the TSCA Incinerator would comply with EPA's RCRA requirements. Specifically, the trial burn evaluated destruction efficiencies for two POHCs, stack gas concentrations of particulate matter, and emission rates of hydrogen chloride. The trial burn considered two different waste feeds, similar to those that would eventually be treated during routine operations. The first waste feed was a combination of contaminated soil, aqueous waste, and organic liquids. The second waste feed was only organic liquid. The POHCs selected for this trial burn were trichlorofluoromethane and carbon tetrachloride.

Table A-2 summarizes the results from this initial RCRA trial burn. In general, the incinerator's performance exceeded the minimum requirements EPA established for DREs of organics, stack gas concentrations of particulates, and emission rates of hydrogen chloride. While this testing strongly suggested that the TSCA Incinerator complied with RCRA requirements, an additional trial burn was conducted one year later. ATSDR has received two accounts for why this additional trial burn was required. By one account, the additional trial burn was conducted to better establish permitting limits on key operating conditions (e.g., combustion temperature, waste feed rates) before routine waste treatment operations began. By the other account, the additional trial bun was required after TDEC ruled the initial test report inconclusive (see Comment #11 in Appendix G). Regardless of which reason is correct, it is important to note that an additional trial burn was conducted before permitted operations could commence. The next item reviews the findings of the follow-up RCRA trial burn.

June 1989 RCRA Trial Burn Retest (IT Corporation 1989)

In June 1989, contractors to DOE conducted a trial burn at the TSCA Incinerator to demonstrate again compliance with EPA's RCRA requirements. The trial burn was designed to measure the destruction efficiency of organic materials, the concentration of particulates in stack gases, and the emission rate of hydrogen chloride. When conducting the trial burn, field personnel followed specifications outlined in a Tribal Burn Plan and a Quality Assurance Project Plan, both of which had multiple versions sent to EPA and TDEC for review and approval. The trial burn challenged incinerator performance by using the highest feed rates allowed (up to 3,000 pounds/hour of combined solid and liquid waste), minimum temperatures in the primary and secondary combustion chambers, and maximum gas flow rates through air pollution controls and the stack. Three POHCs — trichlrofluoromethane, carbon tetrachloride, and hexachloroethane — were selected to evaluate how efficiently the TSCA Incinerator destroys organic waste.

Over the 3-day test, three different stack tests were conducted for the operating parameters specified in the trial burn. These tests, both individually and combined, all showed that the TSCA Incinerator destroyed organic waste constituents without causing elevated emission rates for particulate matter or hydrogen chloride. Of the three POHCs selected, only trichlorofluoromethane was detected in the stack exhaust. These detections suggested that the DRE was at least 99.998%, which surpasses the minimum required DRE of 99.99%. Further, the highest particulate concentration in the stack gases was 0.0327 grains/dscf, which meets the permit restriction of particulate concentrations being no higher than 0.08 grains/dscf. Finally, the air pollution controls were found to remove at least 99.912% of the hydrogen chloride generated during combustion, while the required removal efficiency is only 99%. In short, this trial burn found that the TSCA Incinerator met the main permit restrictions outlined in RCRA waste management regulations.

June 1997 RCRA Metals Trial Burn.

In 1997, TDEC published a report that included a list of historical stack testing activities at the TSCA Incinerator (TDEC 1997). That list mentions a "RCRA Metals Trial Burn" reportedly conducted in June 1997. After reviewing site documents, ATSDR determined this trial burn was actually a performance evaluation of continuous emissions monitoring technologies for metals. Refer to Appendix A.3 for ATSDR's review of the metals emissions data measured during this test.

May 2001 Joint RCRA/TSCA Trial Burn (TRC 2001)

In May 2001, DOE contractors conducted a trial burn to demonstrate compliance with applicable RCRA and TSCA hazardous waste incineration requirements. Another objective of this trial burn was to measure emission rates for use in risk assessments. All testing activities followed specifications in a trial burn plan that DOE contractors prepared and both EPA and TDEC approved. The trial burn lasted nearly 2 weeks, and representatives from both EPA and TDEC observed much of the stack testing.

The trial burn evaluated three different operating scenarios: a combined waste feed of solid wastes (863 pounds/hour) and liquid waste (2,000 pounds/hour), with the waste containing PCBs and other hazardous constituents; a combined waste feed of solid wastes (275 pounds/hour) and liquid wastes (1,070 pounds/hour) containing PCBs; and a feed of entirely liquid wastes (1,370 pounds/hour) containing metals. To ensure that results from individual tests were representative and not spurious, the DOE contractor ran four separate stack tests for each operating scenario. Therefore, the May 2001 trial burn included 12 separate stack tests, with the individual tests typically lasting at least 3 hours. All stack tests were conducted using standard sampling and laboratory analytical methods and according to procedures outlined in the Trial Burn Quality Assurance/Quality Control (QA/QC) Plan. Key findings for the trial burn follow:

Compliance with TSCA requirements

The trial burn found that the TSCA Incinerator destroyed at least 99.9999996% of the PCBs originally in the waste feed. This DRE far exceeds the level (99.9999%) required by TSCA. Also notable was that the total dioxin and furan emission rate was less than 0.054 ng/dscm, expressed on a TEQ basis, which is roughly a factor of four lower than 0.2 ng/dscm — the maximum emission rate EPA has proposed in its most recent regulations for hazardous waste incinerators. Moreover, PCB concentrations in the ash and wastewater residuals were below thresholds mandated by TSCA. Overall, these observations suggest that the TSCA Incinerator efficiently destroyed PCBs without creating hazardous air emissions or toxic residuals.

Compliance with RCRA requirements

To evaluate compliance with RCRA, the DOE contractors selected two POHCs (1,2,4-trichlorobenzene and carbon tetrachloride) for the trial burn. Because these contaminants rank among the most difficult to incinerate, it can be inferred that the waste destruction efficiencies for most other organic compounds are at least as high as those observed for the POHCs. In all of the tests conducted, neither POHC was detected in the stack gases. Using the detection limits for these contaminants, the DRE was reported to be at least 99.9993%, far surpassing the minimum DRE (99.99%) that RCRA requires. The highest hydrogen chloride emission rate measured was 0.11 pounds/hour — nearly 40 times lower than the maximum level allowed by RCRA (4.0 pounds/hour).

Other emissions data (metals and organic compounds). Though designed to characterize compliance with the aforementioned TSCA and RCRA requirements, the 2001 trial burn also measured emission rates of many additional contaminants. For instance, the stack tests included 12 metals: antimony, arsenic, beryllium, mercury, selenium, silver, and thallium were not detected in any of the samples; barium, cadmium, chromium, lead, and nickel were detected. The lead levels measured were safely below the emission limits specified in the incinerator's operating permit. The lack of air permit emission limits for the other metals is not a data gap, as this PHA's conclusions for metals rest largely on the dispersion modeling data and ambient air monitoring data documented in Appendixes B and C, respectively.

DOE contractors also measured air emission rates for 42 VOCs and 20 PAHs. ATSDR's modeling analysis (see Appendix B.3) lists the measured emission rates for the chemicals that were detected and estimates ambient air quality impacts that might result from these emissions. Conclusions cannot be drawn from the emission rates alone; rather, the ambient air concentrations must be compared to health-based comparison values. Refer to Appendix B for this comparison.

Notice of violation for particulate emissions

During the trial burn, particulate concentrations and emission rates were measured under three operating scenarios. Although the particulate *concentrations* in the stack exhaust were safely below the maximum level allowed by RCRA (0.08 grains/dscf), the highest *emission rate* for one of the test conditions (3.7 pounds/hour) exceeded the TDEC air permit emission limit for the source (3.0 pounds/hour) by approximately 25%. As a result, TDEC issued DOE a Notice of Violation (TDEC 2003). It should be emphasized, however, that particulate matter emission rates observed during trial burns are expected to be higher than those during routine operations, given that trial burns are designed to challenge incinerators' operations under unfavorable conditions. Of particulate note, however, is that the waste feed rates routinely used at the incinerator tend to be considerably lower than those used during the trial burns. As a result, the particulate emission rates observed during the trial burns likely exceed those during routine operations. As evidence that the elevated particulate matter emission rates observed during the trial burn are not representative of typical conditions, the TSCA Incinerator has repeatedly complied with TDEC particulate matter emission limits in all performance tests (see Section A.2). Moreover, trends among the extremely extensive ambient air monitoring data for particulate matter (see Appendix C) weighed much more heavily in this site's evaluation, given that ambient air monitoring is a far better measure of the community's potential exposures.

A.2. Performance Tests

DOE and its contractors have conducted four performance tests to obtain and renew the TSCA Incinerator's operating permit with the state of Tennessee. This permit sets maximum emission rates for the following contaminants: particulates, sulfur dioxide, nitrogen oxides, hydrogen fluoride, hydrogen chloride, volatile organic compounds, lead, mercury, and beryllium (TDEC 1991). The permit requires DOE to conduct stack tests every 5 years, starting in 1990, to verify compliance with the permitted emission rates. It is important to note that waste feed rates and other operating parameters during performance tests tend to be more representative of actual operating conditions, while those in trial burns are usually set to challenge incinerator performance. Accordingly, air emissions measured during the performance tests are likely more representative of incinerator's typical emission rates.

ATSDR thoroughly reviewed results of the four performance tests that DOE has conducted to date (see Table A-3). In summary, although a single test conducted before permitted operations began found beryllium and lead emission rates higher than TDEC's emission limits, DOE has since completed three extensive performance tests that show that the TSCA Incinerator efficiently destroys hazardous waste without generating air emissions greater than maximum levels allowed by the state. The following paragraphs review the findings from the individual tests:

November 1988 Performance Test (Martin Marietta 1988)

The purpose of this performance test was to evaluate compliance with TDEC's permitted emission limits for beryllium, fluorine, and lead. DOE was not required to measure emission rates for particulates, chlorine, and sulfur, because the May 1988 trial burn (see Section A.1) had adequately demonstrated compliance for those pollutants. Stack sampling and analytical methods in this performance test followed those outlined in a "pre-test agreement." Representatives from both EPA and the Tennessee Department of Health and Environment observed the test.

The performance test included three separate stack tests, all of which were conducted on November 21, 1988. The test measured emissions for a combined feed of organic waste (contaminated with beryllium and fluorine), aqueous waste (contaminated with lead), and solid waste (contaminated with beryllium, fluorine, and lead). Table A-3 summarizes the test results, which found that fluorine emission rates complied with TDEC's limits but the beryllium and lead emission rates did not. According to DOE, failure to meet the anticipated permit limits might have resulted from miscalculated amounts of beryllium and lead in the waste feed, due to stratification of waste material in the feed tank. Regardless of the cause of the exceedance, DOE was not allowed to operate the TSCA Incinerator routinely until it demonstrated compliance with beryllium and lead emission limits. As the next item indicates, a performance test conducted in June 1990 showed that the TSCA Incinerator could adequately destroy wastes while not exceeding TDEC's emission limits.

Table A-3. Summary of TSCA Incinerator Performance Tests

Parameter	***TDEC Permitted Emissions Limit***	***Emission Rates Measured During Performance Tests***			
		November 1988 Test	***June 1990 Test***	***June 1995 Test***	***November 2000 Test***
Particulate	3.0 lb/hour	Not tested	Not tested	0.18 lb/hour	0.385 lb/hour
Beryllium	0.002 lb/day	*0.0348 lb/day*	< 0.00017 lb/day	0.00016 lb/day	0.0012 lb/day
Lead	3.15 lb/day	*4.61 lb/day*	0.048 lb/day	0.075 lb/day	0.13 lb/day
Mercury	0.48 lb/day	Not tested	Not tested	0.059 lb/day	0.0067 lb/day
Chlorine (as HCl)	3.68 lb/hour	Not tested	Not tested	0.009 lb/hour	0.214 lb/hour
Fluorine (as HF)	0.68 lb/hour	0.023 lb/hour	Not tested	0.002 lb/hour	0.054 lb/hour
Sulfur (as SO_2)	8.8 lb/hour	Not tested	Not tested	0.036 lb/hour	0.036 lb/hour
Summary:		In the November 1988 test, emission rates of beryllium and lead exceeded limits established by TDEC. The elevated emission rates apparently resulted from miscalculations in the waste feed (DOE 1991–2002). Routine operations at the TSCA Incinerator were not allowed until DOE could demonstrate compliance with TDEC requirements, as was done in the test on June 1990. All tests conducted since 1990 have also shown compliance with emission limits.			

Notes: Each performance test involved at least three separate emissions measurements for two different operating scenarios (i.e., liquid waste only and a combination of liquid and solid wastes). Average emission rates were calculated for each operating scenario. The data in the table are the higher of the two average emission rates.

In the November 1988 test, DOE was required to measure emissions of only beryllium, fluorine, and lead. TDEC did not require measurement of particulates, mercury, chlorine, or sulfur, because an earlier trial burn had adequately demonstrated compliance these permit requirements.

Emissions data in italics exceed TDEC emission limits.

The "TDEC Permitted Emissions Limits" shown in this table are those that were active at the time that ATSDR initially prepared this public health assessment. ATSDR has since learned that the permitted emission limits for some parameters have changed, largely to reflect application of Maximum Achievable Control Technology standards for pollutants with limits under that regulation. For instance, ATSDR has been informed that the permitted emission limit for beryllium is now 0.02 pounds per day, rather than 0.002 pounds per day (as shown in the table).

June 1990 Performance Test (IT Corporation 1990).

The purpose of this performance test was to demonstrate compliance with emission limits for beryllium and lead, because an earlier performance test (see previous bulleted item) suggested that the TSCA Incinerator did not meet these requirements. This 3-day performance test followed requirements in a detailed QA/QC Plan, which was approved by representatives from the Tennessee Department of Health and Environment (some of whom observed the stack testing).

The performance test considered waste streams, both liquid and solid, comparable to those considered in the test done in November 1988. Table A-3 summarizes this test's results. In short, beryllium was not detected in any of the stack gas samples, which indicated that the emission rate was less than 0.00017 pounds/day and the system removal efficiency was at least 99.4%. Lead, on the other hand, was detected in stack gases at levels suggesting an emission rate of 0.048 pounds/day — more than 50 times lower than the current permitted limit. The test found that 99.2% of lead in the input waste stream was removed, mostly into the ash. Having successfully demonstrated that beryllium and lead emissions comply with permitted limits, DOE was allowed to begin routine operations of the TSCA Incinerator in 1991.

June 1995 Performance Test (Martin Marietta 1995)

DOE contractors conducted the required performance test on 6 days, between June 26 and July 1, 1995. All testing followed a sampling plan that DOE submitted to TDEC for review and approval. A TDEC representative observed operations and sampling activities on several days of the performance test. All tests were performed using sampling and analytical methods published by EPA and following specifications of a Quality Assurance Project Plan. Multiple quality assurance measures were used, such as analyzing field blanks and method blanks, running laboratory control samples, and analyzing matrix spike samples. The laboratory successfully analyzed all samples collected during the program.

The performance test measured emission rates for two operating scenarios. The first involved only liquid wastes, which were processed, on average, at 888 pounds/hour. These wastes included organic waste, aqueous waste, caustic feed, and ash sump water. The second scenario involved a combined feed of liquid and solid wastes, with a total waste feed of 1,589 pounds/hour. As Table A-3 shows, all emission rates measured during the performance test were below the corresponding limits specified in the TDEC permits. During the tests, the air pollution controls were shown to be highly efficient, with system removal efficiencies in the range of 96% to over 99% for most contaminants (i.e., particulates, hydrogen chloride, sulfur dioxide, beryllium, and lead). As was expected, the system removal efficiency for mercury was near zero. For this reason, the TSCA Incinerator has strict Waste Acceptance Criteria for materials that contain mercury to ensure that emissions are safely below levels that would lead to unacceptable air quality impacts.

November 2000 Performance Test (IT Corporation 2001)

Between November 8 and November 13, 2000, DOE contractors conducted a required performance test to determine compliance with TDEC air emission limits. All sample collection and laboratory analyses involved standard methodologies documented in an Air Performance

Test Plan that DOE submitted to TDEC. Further, the field methods followed specifications in a detailed Quality Assurance Project Plan. The analytical data generated during the performance test appear to be of a known and high quality.

The performance test evaluated two scenarios using feed rates, combustion temperatures, and other parameters that are typical of routine operating conditions. The first scenario involved treating liquid wastes. The feed rates, on average, were 342 pounds/hour of organic waste and 312 pounds/hour of aqueous waste. The second scenario involved treating a combination of solid and liquid wastes, and the average feed rates were 235 pounds/hour of solid waste, 317 pounds/hour of organic waste, and 323 pounds/hour of aqueous waste.

Table A-3 lists the highest emission rates measured during the performance test for particulates, beryllium, lead, mercury, chlorine, fluorine, and sulfur. All emissions were safely below limits established in the TDEC permits. Not shown in Table A-3 are the system removal efficiencies that were observed during the tests. On average, the air pollution control devices removed particulate matter with an efficiency of 98.79% during liquid waste feeds and 99.52% during combined liquid and solid waste feeds. Removal efficiencies of similar magnitude were also observed for hydrogen chloride, beryllium, and lead. Conversely, the incinerator is rather inefficient at removing mercury, due to its high volatility. The mercury removal efficiency during liquid waste feeds is close to 0%; during combined liquid and solid waste feeds, a removal efficiency of 87.3% was observed. For this reason, the TSCA Incinerator has strict Waste Acceptance Criteria for materials that contain mercury.

A.3. Continuous Emissions Monitoring and Continuous Emissions Sampling

In addition to trial burns and performance tests, DOE conducts continuous monitoring and continuous sampling of the TSCA Incinerator's stack gases. "Continuous *monitoring*" refers to nearly instantaneous measurements of stack gas concentrations. Thus, these monitoring devices inform operators of emission rates in real time. "Continuous *sampling*" occurs in devices that continuously collect stack gases while the TSCA Incinerator operates, but, due to technological limitations, release amounts can only be measured at regular intervals (e.g., weekly or monthly), not instantaneously. The following paragraphs summarize results from DOE's continuous monitoring and continuous sampling efforts:

Carbon monoxide, carbon dioxide, and oxygen

Monitoring systems at the TSCA Incinerator continuously measure stack gas concentrations of carbon monoxide, carbon dioxide, and oxygen. Because these gases are relatively benign, certainly in comparison to hazardous air pollutants, this PHA does not evaluate the continuous emissions monitoring data for these compounds. Rather, these three parameters are measured primarily to monitor the incinerator's combustion efficiency and to trigger automatic waste feed cutoffs, as appropriate. Operational data indicate that approximately 30% of the automatic waste feed cutoffs in a recent year resulted from readings from carbon monoxide and oxygen concentrations being too high and too low, respectively (IT Corporation 2000). More details on this continuous monitoring follow:

Carbon monoxide

According to the RCRA permit, 1-hour average concentrations of carbon monoxide (corrected to 7% oxygen) must remain below 100 ppm, as higher levels would indicate poor combustion efficiency. Thus, automatic waste feed cutoffs occur whenever stack carbon monoxide levels exceed permitted limits.

Carbon dioxide

The relative amounts of carbon monoxide and carbon dioxide in the stack gas also characterize the combustion efficiency. Combustion is virtually complete when carbon dioxide levels in the stack are 1,000 times greater than carbon monoxide levels. An automatic waste feed cutoff occurs whenever this balance between carbon monoxide and carbon monoxide levels is not met.

Oxygen

Excess oxygen in the stack gas indicates that ample oxygen is available to support combustion in the rotary kiln and afterburner. Conversely, inadequate combustion might occur when limited oxygen is available in the combustion chambers. Therefore, DOE continuously measures oxygen levels in the stack gas. An automatic waste feed cutoff occurs whenever oxygen concentrations in the exhaust stack fall below 3% by volume.

Metals and particulate matter

Although environmental scientists have worked extensively in recent years to develop robust continuous monitoring technologies for metals and particulate matter, the state-of-the-science in this field continues to emerge. Over the last 5 years, DOE has tested the reliability of several candidate continuous emissions monitoring devices at the TSCA Incinerator, as discussed below:

Metals (other than mercury)

Although environmental regulations do not require DOE to implement continuous emissions monitors for metals at the TSCA Incinerator, DOE has investigated various methods for doing so. Most notably, in 1997, a field study was conducted at the TSCA Incinerator to evaluate the performance of three methodologies, two continuous monitoring devices and one continuous sampling device (Dunn et al. 1998). In the field test, DOE contractors compared emission rates measured by conventional EPA stack sampling techniques to emission rates measured by the candidate technologies. The study found that the two continuous emissions monitoring technologies did not meet the performance criteria for reliably measuring concentrations of metals. But the continuous sampling technology, which involved collecting 7-day average samples for subsequent laboratory analyses, met the performance criteria for several metals.

Because of this study, DOE eventually decided to implement continuous sampling of metals emissions for informational purposes at the TSCA Incinerator, and this system became operational in 1999. Particulate emissions are also obtained from the sampling device through gravimetric analysis of the particulate-bound filter. Annual data reports for this monitoring are currently available for calendar years 2000 and 2001 (DOE 2001, 2002). In these 2 years, stack gas concentrations and emission rates for metals and particulate matter were reported for 52 intervals, most lasting 1 week. The lack of additional data results from incinerator downtime and maintenance to the monitoring equipment. The majority of measurements were collected during routine operations, with the exception of those collected during the May 2001 trial burn.

Table A-4 summarizes the continuous emissions sampling results collected during 2000 and 2001. Overall, these data show that emission rates of beryllium, lead, and mercury complied with TDEC permit limits in every sample that was analyzed. Similarly, every stack gas concentration of low volatile metals (arsenic, beryllium, and chromium) and all but one of the stack gas concentrations of particulates were below the corresponding "maximum achievable control technology" (MACT) standards that EPA had proposed at the time. On the other hand, in 8 out of the 48 valid samples collected outside the trial burn period, the stack gas concentration of semi-volatile metals (lead and cadmium) exceeded concentration limits that EPA would *later establish* in the technology-based MACT standard. This statement is not intended to imply that the incinerator operated out of compliance, especially considering that EPA enacted the MACT standards more than 2 years after these emissions data were collected. Readers should refer to Appendix C and Section III of the PHA for a more complete evaluation of the air quality issues for lead and cadmium, given that ambient air has been monitored for these metals in the vicinity of the TSCA Incinerator for more than 10 years.

Table A-4. Summary of Continuous Emissions Sampling Data for Metals and Particulate Matter Collected in 2000 and 2001

Parameter	*Regulatory Limit****	*Source of Regulatory Limit*	*Number of Measured Values Found Below Regulatory Limit (Maximum = 48)*
Beryllium	0.002 lb/day	TDEC permit	48 (or 100%)
Lead	3.15 lb/day	TDEC permit	48 (or 100%)
Mercury	0.48 lb/day	TDEC permit	48 (or 100%)
	130 µg/dscm	MACT	48 (or 100%)
Low volatile metals	97 µg/dscm	MACT	48 (or 100%)
Semi-volatile metals	240 µg/dscm	MACT	40 (or 83%)
Particulates	0.015 grains/dscf	MACT	47 (or 98%)

Notes: The regulatory limits in this table include both stack concentrations (i.e., those expressed in µg/dscm and grains/dscf) and emission rates (i.e., those expressed in lb/day).
Low-volatile metals include concentrations of arsenic, beryllium, and chromium.
Semi-volatile metals include concentrations of cadmium and lead.
Emissions data collected during the May 2001 trial burn are not included in this tally.
***The MACT limits represent "maximum achievable control technology" among hazardous waste incinerators. Thus, these values are technology-based and not necessarily health-based. Moreover, these standards came into effect on September 30, 2003 — more than 2 years after the air sampling results summarized above were collected. Comparisons to the MACT standards are presented merely to identify the metals that warrant closer inspection in the ambient air monitoring data.

Mercury.

The previous item summarizes continuous emissions sampling data available for particulate matter. In addition, DOE has recently completed an evaluation of six candidate continuous mercury emissions monitoring devices (Dunn et al. 2003). This evaluation involved two test conditions, in which measurements made using continuous emissions monitors were compared to those made with conventional EPA sampling methodologies. While some of the mercury monitoring devices showed great promise, only one met the accuracy criteria in the first test condition. Accordingly, Section III of this PHA draws from the continuous sampling data (as summarized in Table A-4), rather than the limited continuous monitoring data, to evaluate the TSCA Incinerator's mercury emissions.

Particulate matter

DOE has also recently evaluated the viability of three commercially available continuous emissions monitoring devices for metals and particulate matter (IT Corporation 2002). After characterizing the measurement accuracy and reliability of the three devices in a 15-month field study, DOE contractors recommended use of a particulate matter monitor in future continuous emissions monitoring applications. During a March 2004 site visit to the TSCA Incinerator, ATSDR scientists learned that DOE was preparing to install the continuous particulate monitor. ATSDR does not consider the lack of validated continuous emissions monitoring data for particulates to be a critical data gap for this PHA, given that numerous performance tests have been conducted to date (see Table A-3), that continuous emissions sampling data are available (see Table A-4), and that an extremely large volume of particulate ambient air monitoring data have been collected (see Appendix C).

Radionuclides

While continuous emissions monitoring data for radiounclides is clearly desirable, ATSDR is not aware of any technology that can provide such measurements accurately and precisely. On the other hand, continuous emissions sampling for radionunclides is not only feasible, but a required element in one of DOE's environmental permits for the TSCA Incinerator. Accordingly, from 1991 to the present, DOE has operated a continuous emissions sampling system on the TSCA Incinerator's main exhaust.

The system includes a filter sampling mechanism to collect particle-bound contaminants and impingers to collect gaseous contaminants. At the end of every week, DOE archives both sampling media. Then, at the end of every month, DOE composites the month's individual samples and sends this composite to a laboratory for analysis using appropriate methodologies. Annual emissions data are eventually reported in DOE's Annual Site Environmental Reports (DOE 1991–2002).

ATSDR reviewed the emissions data that DOE has collected over the entire time during which the TSCA Incinerator operated. Table A-5 lists the highest annual emission rates reported for the radionuclides that were detected most frequently. The modeling and monitoring studies reviewed in Appendixes B and C, respectively, document estimated radiation doses and measured ambient air concentrations of radionuclides, which ATSDR used to reach conclusions regarding these contaminants.

Table A-5. Summary of Continuous Emissions Sampling Data for Selected Radionuclides

Radionuclide	*Highest Measured Annual Emission Rate (Ci)*
Cesium-137	0.0050
Neptunium-237	0.00081
Plutonium-238	0.00085
Plutonium-239	0.000050
Technetium-99	0.11
Thorium-228	0.0027
Thorium-230	0.00047
Thorium-232	0.00070
Thorium-234	0.047
Uranium-234	0.023
Uranium-235	0.00092
Uranium-238	0.036

Notes: Source of emission rate data: DOE 1991–2003. Data are presented for the radionuclides that were reported in at least 10 years of the TSCA Incinerator's operational history.

Appendix B: Review of Fate and Transport Modeling Studies

ATSDR views ambient air monitoring data and ambient air sampling data as critical inputs to the public health assessment process for air pathway evaluations. As evidence of this, ATSDR strongly recommends the use of validated sampling data, where available, as the basis for public health decisions. In some circumstances, however, air quality measurements are not sufficient to characterize all site-specific exposures. For instance, ambient air monitoring and ambient air sampling may not have been conducted over all time frames, at all locations of interest, or for all contaminants of concern. In such cases, air dispersion models are arguably the best tools available to evaluate the nature and extent of contamination. ATSDR emphasizes that models are only capable of *estimating* exposure concentrations, based on a scientific understanding of how contaminants move in the environment. All models have assumptions and uncertainties and may not accurately represent actual environmental or topographic conditions. Therefore, ATSDR carefully reviews all modeling applications to determine whether they provide meaningful estimates of environmental contamination and whether they can be used in the public health assessment process.

ATSDR identified two major air dispersion modeling studies for the TSCA Incinerator. The independent panel previously chartered by the Governor of Tennessee conducted one study (see Appendix B.1), and DOE conducted the other (see Appendix B.2). To supplement these studies, ATSDR performed an additional brief modeling evaluation that builds upon the independent panel's study (see Appendix B.3). Combined, all three modeling efforts estimate ambient air concentrations at ground level for all eight groups of contaminants that this PHA considers, thus leaving no major data gaps. It should be noted that dispersion modeling results have been documented in other studies (e.g., DOE's past trial burn plans). While this appendix focuses on the major studies identified above, ATSDR factored the findings from all available modeling studies into the conclusions of this PHA. Refer to Section III.E of this PHA for a discussion of how the air dispersion modeling results support ATSDR's overall environmental health conclusions for this site.

B.1. Independent Panel's Modeling Study (Iglar et al. 1998)

The independent panel chartered by the Governor of Tennessee to evaluate the TSCA Incinerator's air quality impacts conducted a dispersion modeling analysis of PCBs, particulate matter, acidic gases, selected metals, and selected VOCs. The study considered waste treatment data for calendar years 1994, 1995, and 1996 — three of the four years with the highest process throughputs at the TSCA Incinerator. Annual average air concentrations at ground level were estimated for the most toxic contaminants that were processed in greatest quantities. A detailed review of the modeling study follows:

Emissions estimation approach

Emission rates are arguably one of the most critical inputs to air dispersion models. For total PCBs, each metal, and each VOC, the independent panel estimated emission rates by multiplying an annual waste feed quantity and the estimated DRE. The waste feed rates used in these calculations were the highest contaminant-specific rates observed in calendar years 1994, 1995, and 1996. The following DREs were used: 99.9999% for PCBs, between 95% and 98.5% for metals (except for mercury, which was assumed to have a DRE of 0%), and 99.99% for VOCs. ATSDR believes this calculation approach is sound, given that trial burns demonstrated that the TSCA Incinerator achieves the aforementioned efficiencies even under operating conditions that do not favor complete combustion. For particulate matter, the modeling analysis assumed an annual emission rate of 1.32 tons/year. No supporting data are provided for selecting this emission rate; however, the number appears to significantly overstate actual emissions, given that DOE reported particulate matter emission rates from the TSCA Incinerator to be no higher than 0.096 tons/year between 1994 and 1996 (DOE 1991–2002). Overall, ATSDR believes the independent panel used reasonable emissions data in the modeling analysis for the time frame under consideration.

Air dispersion modeling approach

The independent panel used the Industrial Source Complex Short Term (ISCST) model, version 3, to simulate how contaminants move from the TSCA Incinerator stack through the air to locations where people might be exposed. ISCST is listed among EPA's regulatory guideline models for evaluating emissions from industrial sources. Modeling options were generally consistent with regulatory defaults: building downwash effects were considered, deposition was not considered (causing the analysis to overstate potential air quality impacts), and urban dispersion coefficients were used to reflect the industrial nature of the ETTP site. ATSDR believes that all of these options, plus others not specified here, were appropriate for this modeling application.

The independent panel's modeling analysis was based on meteorological data collected at ETTP in 1989, 1991, 1992, 1994, and 1995. At the time the modeling analysis was conducted, these were the five most recent and complete years of meteorological data. Wind roses for these years are similar to the one depicted in Figure 6 of this PHA. The modeling analysis predicted the air quality impacts at hundreds of locations over an area that extends 3 miles in all directions from the TSCA Incinerator. Elevations at each of the receptors were programmed into the dispersion model to account for potential plume impaction at locations in elevated terrain. This approach is commonly referred to as assessing terrain effects using "flagpole receptors." While this approach may not be as rigorous as using dispersion models developed specifically for complex terrain applications, the approach does provide reasonable insights on the higher air quality impacts that might occur when plumes reach terrain features.

Readers interested in a detailed account of the modeling inputs should refer to pages 67 to 82 of the Independent Panel's summary report (Iglar et al. 1998), a copy of which should be available from the record repositories. Information on the ISCST model can be found in the User Manual (EPA 1995), also available at http://www.epa.gov/ttn/scram/userg/regmod/isc3v2.pdf.

Results

The independent panel's modeling analysis revealed several notable findings. Not surprisingly, the greatest air quality impacts were predicted to occur in the main downwind directions, both northeast and southwest of the TSCA Incinerator. The location with the highest estimated ground-level impacts was 640 meters (0.4 miles) southwest of the main stack. Results for the point of maximum impact are reviewed here, even though this location is within the ETTP property line. The model predicted considerably lower ambient air concentrations at locations further downwind. At the point of maximum impact, the modeling found, the estimated annual average concentration is 1.75 $\mu g/m^3$ for every gram/second of contaminant emitted — a result that ATSDR incorporated into a separate modeling analysis (see Appendix B.3).

Table B-1 summarizes the independent panel's modeling results. Specifically, the table presents the estimated annual average concentrations at the point of maximum impact alongside health-based comparison values. With one exception, every estimated concentration was safely below the comparison values. For many contaminants, including all of the organic compounds, the estimated concentrations at the point of maximum impact are more than 1,000 times lower than health-based comparison values.

The estimated concentration of total chromium, however, exceeded the comparison value for hexavalent chromium. This is not an ideal comparison, given that the amounts of hexavalent chromium within the total chromium are not known. Nonetheless, ATSDR selected chromium as a contaminant of concern that requires a more detailed health evaluation, which is presented in Section IV of this PHA.

Limitations and uncertainties

Like all air quality modeling analyses, the independent panel's study has limitations and uncertainties. The entire study is, for example, based on waste treatment data for just 3 years. ATSDR does not view this as a critical limitation, given that the modeling considers years (1994–1996) when incinerator operations were near their highest. To ensure that focusing on this narrow time frame did not cause the modeling analysis to overlook key issues, ATSDR's modeling evaluation (see Appendix B.3) builds upon the independent panel's study by considering a longer time frame and a broader range of contaminants.

The independent panel's modeling analysis has multiple sources of uncertainty, due both to the inherent limitations of atmospheric dispersion models and the incomplete characterization of all inputs. ATSDR has, however, several reasons to believe that the independent panel's modeling analysis tends to overstate, and not understate, the actual exposure concentrations that residents have experienced. First, the independent panel calculated emissions based on the lowest allowed DREs, even though the trial burns have shown that the TSCA Incinerator is typically much more efficient. Second, the emissions data also are based on some of the highest waste feed rates (1994–1996). For comparison, total annual waste feed rates in the past 3 years have been approximately 4 times lower than those observed in the mid-1990s. Finally, the conclusions of the modeling study are based on estimated concentrations for an on-site location. Estimated concentrations at off-site locations were considerably lower than the levels shown in Table B-1. Taken together, these observations suggest that the modeling may have overstated actual exposures. ATSDR is further comforted by the fact that most of the estimated concentrations in Table B-1 are multiple orders of magnitude lower than health-based comparison values. That the modeling analysis understated exposures by such large margins is extremely unlikely.

Overall, ATSDR finds the independent panel's modeling analysis to be a reasonable account of the TSCA Incinerator's air quality impacts between 1994 and 1996. ATSDR concurs with the independent panel's conclusion that none of the pollutants evaluated had estimated ambient air concentrations at levels of public health concern.

Table B-1. Evaluation of Independent Panel's Air Dispersion Modeling Results

Contaminant	*Estimated Annual Average Concentration (μg/m³) at Point of Maximum Impact*	*Health-Based Comparison Value (μg/m³)*	*Type of Comparison Value*
Modeling results for metals			
Antimony	0.00222	1.5	RBC-N
Arsenic	0.000148	0.0002	CREG
Barium	0.00104	0.51	RBC-N
Beryllium	0.000001	0.0004	CREG
Cadmium	0.000129	0.0006	CREG
Chromium (total)	0.000153	0.00008	CREG (see notes)
Lead	0.000333	1.5	NAAQS
Mercury	0.000215	0.2	EMEG-chronic
Nickel	0.00107	0.09	EMEG-chronic
Silver	0.000014	18	RBC-N
Thallium	0.000012	0.26	RBC-N
Modeling results for particulate matter			
Particulate matter	0.067	50	NAAQS
Modeling results for organic compounds			
Acetone	0.000027	31,000	EMEG-chronic
Acetonitrile	0.000009	60	RfC
Acrolein	0.000009	0.02	RfC
Acrylonitrile	0.000009	0.01	CREG
Benzene	0.000001	0.1	CREG
Carbon tetrachloride	0.000025	0.07	CREG
Chloroform	0.000004	0.04	CREG
Hexachloroethane	0.000005	0.3	CREG
Methylene chloride	0.000031	3	CREG
PCBs	0.000003	0.01	CREG
Tetrachloroethylene	0.000158	270	EMEG-chronic
Toluene	0.000021	300	EMEG-chronic
Trichloroethylene	0.000091	540	EMEG-intermediate
Xylenes	0.000018	0.1	RfC
Modeling results for radionuclides			
Uranium (total)	0.002	0.017	See notes below

Notes: Modeling results taken from the independent panel's report (Iglar et al. 1998).
Refer to Appendix D for more information on the comparison values used and definitions for the abbreviations. The comparison value for uranium is the exposure concentration that would result in an annual radiation dose of 10 mrem, assuming that all of the uranium found is uranium-238 (Iglar et al. 1998).
Chromium is the only contaminant with an estimated concentration greater than its comparison value. The estimated concentration is for total chromium and the comparison value is for hexavalent chromium, which is a subset of total chromium. Section IV of the PHA discusses this issue further.

B.2. DOE's Modeling for NESHAPs (DOE 1997–2002, 1991–2002)

EPA's National Emissions Standards for Hazardous Air Pollutants (NESHAPs) require selected facilities to demonstrate that their air emissions of radionuclides do not cause members of the public to have effective dose equivalents greater than 10 mrem/year. To fulfill its regulatory requirements, DOE characterizes air emissions of radionuclides across all its facilities and uses models to estimate radiation doses that might result. Findings are documented in annual reports that DOE submits to EPA (DOE 1997–2002). The following paragraphs review the scope and findings of the modeling analyses conducted at ORR:

Emissions estimation approach

The NESHAP modeling evaluates radionuclide emissions from selected stack sources at all three major ORR facilities: ETTP, Y-12, and Oak Ridge National Laboratory (ORNL). Included in this modeling are radionuclide emissions data from the TSCA Incinerator, as derived from the continuous emissions sampling system (see Appendix A.3). Thus, the NESHAP air dispersion modeling efforts are based primarily on measured emissions data, not on estimated emissions data. DOE did estimate radionuclide releases that occurred during TRV openings. Therefore, the modeled air quality impacts consider contributions from both non-routine releases through the TRV and routine releases through the main process stack.

Air dispersion modeling approach

Air dispersion and dose modeling was conducted using EPA's Clean Air Assessment (CAP-88) software, which is a set of computer programs designed to estimate dose and risk from air emissions of radionuclides. The main inputs to the model are source-specific emission rates and local meteorological data, from which the model estimates environmental concentrations of radionuclides. The model assesses both external and internal radiation exposure, not only from inhaling and otherwise contacting airborne radionuclides but also from ingesting radionuclides that might be taken up into the food chain. DOE runs the model using typical default parameters and assumptions, some of which likely overstate potential exposures. For instance, the modeling analysis assumes that 70% of the vegetables and 44% of the meat in residents' diets come from local farms. More information on the CAP-88 model can be found from an EPA website describing the model (http://www.epa.gov/radiation/assessment/CAP88/) or in the model User Guide (Trinity Engineering Associates 2002).

Results

DOE has conducted radionuclide modeling for every year that the TSCA Incinerator has operated. Table B-2 summarizes the main findings from these modeling analyses and shows that the estimated effective dose equivalent to the off-site maximally exposed individual has been no more than 1.7 mrem/year from 1991 to 2002. This dose equivalent reflects contributions from all radionuclide emissions sources at ORR, not just the TSCA Incinerator. The estimated effective dose equivalent resulting from ORR operations (<1.7 mrem/year) not only complies with NESHAP requirements, but also amounts to less than 1% of the radiation dose that U.S. citizens receive, on average, from natural sources.

Table B-2 also identifies which radionuclides accounted for the majority of off-site radiation exposures. Between 1991 and 2002, uranium isotopes accounted for approximately 80% of the off-site radiation exposures attributed specifically to the TSCA Incinerator. The remaining incinerator-related doses resulted primarily from exposures to tritium and isotopes of neptunium, plutonium, potassium, technetium, and thorium.

Limitations and uncertainties

DOE's radionuclide modeling for the NESHAP regulations has inherent uncertainties and limitations. The significance of the modeling uncertainties on ATSDR's public health evaluation is, however, limited because an extremely large set of validated ambient air monitoring data are available to support the modeling predictions. As Section III.E of this PHA explains, ATSDR's conclusions for the TSCA Incinerator are based on the combined findings of emissions studies, fate and transport modeling analyses, and ambient air monitoring data — all three of which are reasonably consistent in suggesting that the incinerator's emissions of radionuclides do not cause unhealthful environmental exposures among nearby residents.

In summary, DOE's annual modeling studies for radionuclides suggest that air emissions from the TSCA Incinerator (and, more generally, from all of the ORR facilities) have consistently complied with the health-protective NESHAP regulations. These studies are notable in that they evaluate environmental contamination for radionuclides, a group of contaminants that the other modeling studies did not consider in detail. ATSDR believes DOE's modeling studies, combined with the extensive ambient air monitoring results, provide an adequate basis for public health conclusions about exposures to radionuclides from the TSCA Incinerator.

Table B-2. Results of DOE's Modeling of Radionuclide Emissions

Year	*Estimated Effective Dose Equivalent to the Off-site Maximally Exposed Individual (Regulatory Limit = 10 mrem/year)*	*Radionuclides that Account for the Majority of the Effective Dose Equivalent Associated with ETTP Releases*
1991	1.7 mrem/year	Uranium (75%), thorium (17%), and neptunium (7%)
1992	1.4 mrem/year	Uranium (89%), thorium (7%), and plutonium (3%)
1993	1.4 mrem/year	Uranium (77%), neptunium (10%), and thorium (8%)
1994	1.7 mrem/year	Uranium (80%), neptunium (9%), and thorium (6%)
1995	0.5 mrem/year	Uranium (93%), potassium (6%), and technetium (1%)
1996	0.45 mrem/year	Uranium (95%), thorium (2%), and plutonium (1%)
1997	0.41 mrem/year	Uranium (87%), thorium (9%), and plutonium (1%)
1998	0.73 mrem/year	Uranium (74%), thorium (9%), and plutonium (2%)
1999	0.7 mrem/year	Tritium (50%), uranium (36%), thorium (12%), and plutonium (2%)
2000	0.4 mrem/year	Uranium (93%), thorium (6%), and tritium (1%)
2001	0.78 mrem/year	Uranium (72%), tritium (14%), and thorium (13%)
2002	0.29 mrem/year	Uranium (90%), thorium (5%), tritium (2%), and plutonium (2%)

Notes: Source of data: DOE 1991–2002.
The estimated effective dose equivalents were calculated from air emissions of radionuclides from point sources at all three main ORR facilities (ETTP, ORNL, and Y-12), not just from the TSCA Incinerator. Each dose in the table is for the residential location most impacted by releases from the ORR facilities.
The NESHAP regulations require industrial facilities' incremental increase to off-site radiation doses to be no more than 10 mrem/year. On average, United States residents receive a dose of 300 mrem/year from natural sources of radiation.

B.3. ATSDR's Modeling Evaluation

ATSDR conducted a separate air dispersion modeling evaluation that addresses two key limitations in the independent panel's analysis: ATSDR's evaluation considers a broader range of air contaminants and is based on waste treatment data for the entire history of the TSCA Incinerator's operation, not just the data available at the time the independent panel evaluated the site. ATSDR estimated ambient air concentrations by multiplying an emission rate (either measured or estimated, as described below) by the dispersion factor that the independent panel derived. That factor indicates that, at the point of maximum impact, the estimated ambient air concentration is 1.75 $\mu g/m^3$ for every gram per second of contaminant emitted. Because the point of maximum impact is actually within the ETTP property boundary, use of this dispersion factor very likely overstates exposure concentrations that off-site residents might have experienced. Thus, use of the dispersion factor should be considered a health-protective approach, in that ATSDR has chosen to err on the side of overestimating exposure concentrations.

ATSDR's modeling evaluation applies a single dispersion factor to all groups of contaminants considered. This single dispersion factor was derived assuming that all emitted contaminants remain airborne and are not consumed by chemical reactions or removed from the plume by wet or dry deposition. By not accounting for these removal mechanisms, the dispersion factor actually overstates the amount of contaminants that remain in the air. Therefore, ATSDR's approach of applying this single dispersion factor to all groups of contaminants likely overstates actual air quality impacts. Furthermore, the dispersion behavior of gaseous pollutants in the ISC model is almost entirely driven by meteorological conditions, not physical or chemical parameters of the individual pollutants.

ATSDR's modeling analysis focuses on five groups of contaminants: VOCs, PCBs, PAHs, acidic gases, and dioxins and furans. These groups were selected because they have relatively few, if any, ambient air monitoring data available. ATSDR did not consider air emissions for the remaining three groups of contaminants (i.e., particulate matter, radionuclides, and metals), because an extremely large volume of information — emissions data, modeling results from the Independent Panel, and air sampling and monitoring data — already suggest that even the highest air quality impacts from the TSCA Incinerator are below levels of health concern. Thus, ATSDR decided to allocate its resources on the groups of pollutants for which notable information gaps remained, after careful consideration of all other data sources. Following are detailed descriptions of the contaminant-specific modeling approaches and results:

VOCs and PCBs

The independent panel's modeling results for VOCs and PCBs are based on the amounts of these contaminants found in the waste feed between 1994 and 1996. ATSDR built upon these findings by considering waste treatment quantities reported through 2003. For PCBs and every VOC listed in Table B-1, the highest annual waste treatment quantity actually occurred between 1994 and 1996. One can infer from this trend that the air quality impacts for PCBs and VOCs between 1997 and the present have not exceeded the estimated concentrations shown in Table B-1, assuming that the TSCA Incinerator continues to meet the required DREs.

To build further upon the independent panel's modeling analysis, ATSDR considered potential air quality impacts for a much broader range of VOCs. In addition to considering the 13 VOCs shown in Table B-1, DOE now characterizes waste treatment quantities for more than 150 other organic compounds, mostly volatile. After reviewing the entire history of VOCs and other organic compounds fed to the incinerator, ATSDR found that the maximum annual waste feed for all compounds (except for those shown in Table B-1) was less than 10,000 pounds per year. Using this waste feed rate, an assumed DRE of 99.99%, and the dispersion factor, the annual average concentration at the point of maximum impact for all other VOCs likely does not exceed 0.00003 $\mu g/m^3$. This annual average concentration is well below corresponding health-based comparison values for the many other VOCs that the incinerator treats. Although published comparison values are not available for all VOCs, ATSDR is reassured by the fact that the estimated annual average concentration is almost immeasurably small at the point of maximum impact; in residential areas, the TSCA Incinerator's air quality impacts for VOCs are undoubtedly lower.

PAHs

In the 2001 trial burn, DOE measured air emission rates of PAHs during six different stack tests. Three of these six tests were performed using waste feeds composed entirely of liquid wastes, in quantities that averaged 1,370 pounds/hour. The other three tests were conducted with a combined waste feed of solid wastes (average feed rate of 863 pounds/hour) and liquid wastes (average feed rate of 2,000 pounds/hour). Emission rates were measured for 20 individual PAHs, from which DOE calculated emission rates for total PAHs. Across all six tests, the highest emission rate for total PAHs was 0.00000312 grams/second.

Using the highest measured emissions rate and the independent panel's dispersion factor, ATSDR calculated a maximum annual average concentration of total PAHs to be 0.000005 $\mu g/m^3$. Even if one assumes that the total PAHs are composed entirely of the most potent individual compound, the estimated concentration is more than 150 times lower than the corresponding risk-based concentration.

Acidic gases

The independent panel's modeling analysis estimated air emissions of hydrogen chloride and hydrogen fluoride from the amounts of chlorine and fluorine in the waste feed and an assumed removal efficiency of the air pollution control devices. While such an approach is reasonable, ATSDR built upon it by evaluating air quality impacts for these compounds using measured emission rates. Specifically, among all performance tests and trial burns (see Appendix A) conducted to date, the maximum measured emission rates for hydrogen chloride and hydrogen fluoride are 0.214 pounds/hour and 0.054 pounds/hour, respectively. Given these emission rates and the independent panel's dispersion factor, the estimated annual average concentrations of hydrogen chloride and hydrogen fluoride at the point of maximum impact are 0.047 $\mu g/m^3$ and 0.012 $\mu g/m^3$, respectively. Both of these estimated concentrations are more than 400 times lower than the chemicals' lowest health-based comparison values.

Dioxins and furans

Neither modeling study reviewed above evaluated potential air quality impacts of dioxins and furans. To fill this data gap, ATSDR considered the dioxin and furan emissions data recently measured during the 2001 trial burn. Like the PAHs, dioxins and furans were measured in six separate stack tests over the course of the trial burn. During three tests, the incinerator was treating liquid wastes; during the other three tests, the incinerator treated a combination of liquid and solid wastes. Across all six tests, the highest total emission rate of dioxins and furans was 0.214 ng/second, expressed on a toxic equivalency (TEQ) basis.7 This emission rate is the sum of emissions of all dioxin and furan congeners. In cases where congeners were not detected, the detection limit was used in the emission rate calculation, which is an approach taken to be health-protective.

7 The TEQ basis allows for evaluating mixtures of numerous dioxin and furan congeners using a single exposure concentration. Rather than evaluating the health implications of each congener individually, one can compute a TEQ concentration that characterizes the toxicity of the entire mixture. TEQs are calculated by weighing the individual dioxin and furan congeners by toxic equivalency factors (TEFs). The most toxic congener (2,3,7,8-tetrachlodibenzo-p-dioxin) is assigned a TEF of 1, and all other congeners have lower factors.

Multiplying the emission rate by the independent panel's dispersion factor and assuming that the TSCA Incinerator routinely operates under conditions similar to those used during the trial burn, ATSDR estimates that the annual average concentration of total dioxins and furans at the point of maximum impact is 3.75 x 10^{-10} $\mu g/m^3$ on a TEQ basis. Besides being immeasurably small, this estimated concentration is more than 100 times lower than the risk-based concentration for the most toxic dioxin congener. Moreover, calculations based on proposed EPA methodologies (EPA 1998) and the estimated concentrations suggest that dioxins and furans released by the TSCA Incinerator present theoretical cancer risks of approximately 1 in 100,000,000 — far below levels that typically cause environmental regulatory agencies to take action.

Limitations and uncertainties

ATSDR's modeling evaluation builds upon the modeling conducted by the independent panel by considering measured emissions data and waste treatment amounts over the entire history of the TSCA Incinerator operations. While this analysis is therefore more extensive than the early modeling efforts, ATSDR's modeling evaluation has limitations and uncertainties. For instance, ATSDR's evaluation considers only routine releases through the main process stack, without considering contributions from TRV openings. This is a notable limitation, but one that is accounted for by the ambient air sampling that has occurred during these events (see Section III.D.2). Further, emissions data used in ATSDR's modeling are collected during discrete tests and might not represent emissions trends over the long term. Still, most emissions data used in the modeling were collected during trial burns, which typically challenge incinerator performance and lead to higher emissions than might be observed otherwise. Further, when using trial burn data, ATSDR always selected the highest measured emission rate across all individual stack tests, rather than selecting the average emission rate. This approach, which likely overstates the incinerator's potential air quality impacts, was taken to make the modeling analysis more protective of public health.

While none of the previous observations quantify the impact of uncertainty in the modeling analysis, ATSDR notes that the estimated ambient air concentrations for acidic gases, PAHs, dioxins, and furans are all at least 100 times lower than levels that might warrant more detailed evaluations. Thus, even if measured emission rates understate actual releases, perhaps by a factor of 100, estimated ambient air concentrations for these contaminants would still be lower than the most conservative health-based comparison values. ATSDR has no reason to believe that the emissions data would be this inaccurate. Therefore, the considerable margin between the estimated ambient air concentrations and their corresponding health-based comparison values gives ATSDR greater confidence that the modeling results form an adequate basis for reaching conclusions.

The purpose of ATSDR's modeling analysis was to account for limitations in the independent panel's modeling study. Section III.C of this PHA brings together the conclusions from all three modeling studies reviewed in this appendix, and Section III.E integrates the modeling results with findings from the emissions data and ambient air monitoring data.